Calibration of Data - Lab

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Brief Summary of Lab

⌘ Why and how to pick a calibrator?

⌘ ISC calibration tools (PTI and KI)

⌘ Target vetting criteria

⌘ Sample systems to try out

⌃ Lab demos

⌘ Overview of samples

Why do we care about calibration?

⌘ Interferometer response function

- ⌃ system visibility - uniform disk
- ⌃ $|V|^2 = (2 J_1(x) / x)^2$ where $x = \pi B \vartheta / \lambda$

⌘ System response

- ⌃ geometry with respect to target
- ⌃ brightness
- ⌃ color
- ⌃ bolometric flux - $F_{bol} = \pi\sigma T^4/m$ where m - best fit factor

Known Solutions

- binaries, resolved stars, circularly symmetric, simple geometry, limb-darkening, etc.

Peripheral Knowledge

- estimated angular diameter
- astrophysics of source (e.g. variability)
- spectral energy distribution (SED)
- Hipparcos/SIMBAD/ADS classifications

Scientific Experiment - goals

Tools - getCal and gcGui

⌘ Written by A. F. Boden as part of PTI reduction tools suite. Now upgraded and maintained by ISC at IPAC/Caltech for use with Keck Interferometer.

- getCal is original command line interface
- gcGui is updated GUI with most common functions and additional modules for added functionality

getCal GUI: The Basics

List of potential calibrators

getCal Return -- mira

/proj/isc/iscSoftware/src/tools/planning/getCal/getCal-2.4/getCal -targetName mira -search

```
### GUI catalog from getCal v2.4pre5 ###
# Resolving target mira via SIMBAD
# target HD 14386
# HIP 10826 (HD 14386) has his variability flag set (3)
#   with 1.303 mag scatter in  82 observations
# Simbad Search HD 14386: Type: Variable Star of Mira Cet type  M7IIIe V=3.04
HDC14386 02 19 20.793 -02 58 39.513  0.010 -0.239 6.5 6.5 M5e-M9e 0.0 xxx   xxx   trg
# HIP 8998 (HD 11803) has his multiple component flag set to C
#   the C designation indicates solutions were found for individual components
#     2 components:
#      B component -- V= 6.844
#      A component -- V= 6.936 at sep 1.163 arcsec/PA 238 deg
# Simbad Search HD 11803: Type: Variable Star  F7V+...  V=6.01
HDC11803 01 55 53.832 +01 50 59.935  0.159  0.190 6.0 4.7 F7V+... 7.6 0.36+/-0.2  cal HDC1
# Simbad Search HD 12641: Type: Variable Star  G5II-III+...  V=5.956
HDC12641 02 03 48.171 -00 20 24.903  0.083 -0.043 6.0 4.4 G5V... 4.7 0.33+/-0.5  cal HDC14
# Simbad Search HD 13456: Type: Star  F5V V=6.008
HDC13456 02 11 22.226 -10 03 07.783 -0.028 -0.171 6.0 4.9 F5V 7.3 0.32+/-0.2  cal HDC14386
# HIP 10305 (HD 13612) has his multiple component flag set to C
#   the C designation indicates solutions were found for individual components
#     1 components:
#      A component -- V= 5.772
# HIP 10305 (HD 13612) has his astrometric source flag set to P
#   with solution quality listed as A
# Simbad Search HD 13612: Type: High proper-motion Star  F8V V=5.68
HDC13612 02 12 47.542 -02 23 37.094  0.375 -0.073 5.7 4.3 F8V 1.7 0.39+/-0.3  cal HDC14386
# Simbad Search HD 14691: Type: Star  F0V V=5.437
HDC14691 02 22 01.532 -10 46 39.121  0.156 -0.082 5.4 4.7 F0V 7.3 0.45+/-0.1  cal HDC14386
# HIP 11046 (HD 14690) has his variability flag set (1)
#   with 0.006 mag scatter in  88 observations
```

Save   Close
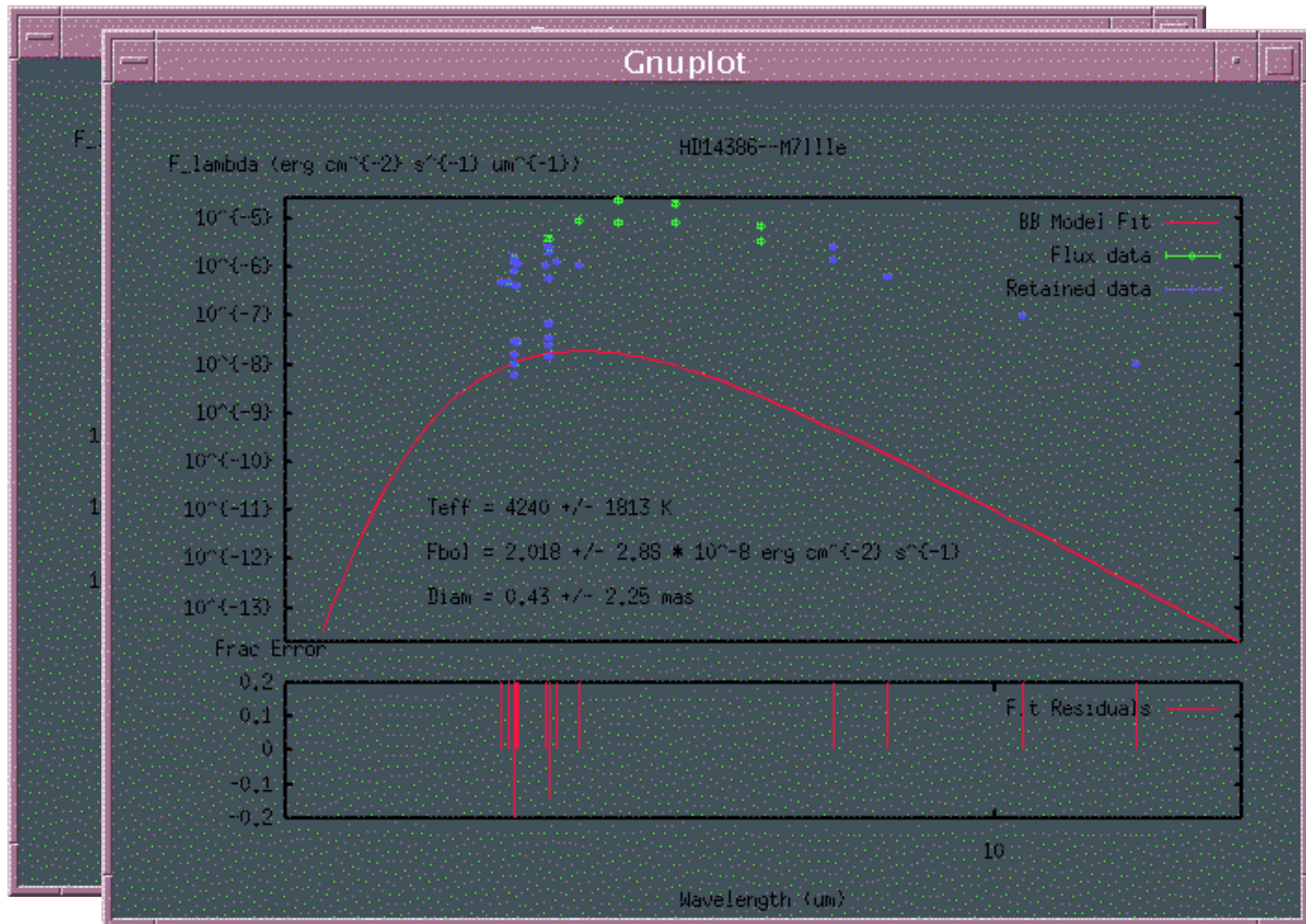
Bolometric flux information

getCal Return -- mira

```
### Bolometric Flux Diameter Fit results ###
# option stdin
# 1 command line arguments processed
#                              ChiSqr           F_bol (10^-8        Ang
#     Star          Teff(K)    /DOF    DOF      erg/cm2/s)      Size (mas)    Filters
    1 HD11803--F7V+...   6002 +/-  67    0.22   17   12.26 +/- 0.174   0.53 +/- 0.09   .XXXXXX...
    2 HD12641--G5II-III+...  4657 +/-  38    0.25   19   15.83 +/- 0.335   1.01 +/- 0.16   .....XX
    3 HD13456--F5V    6554 +/- 142    0.31   22   11.78 +/- 0.211   0.44 +/- 0.10   ......XXX..
    4 HD13612--F8V    6212 +/-  73    0.16   32   15.96 +/- 0.206   0.57 +/- 0.09   ..........XX
    5 HD14386--M7IIIe  4240 +/- 1813   75.34  35    2.018 +/- 2.88   0.43 +/- 2.25   .XXXXXXXXXX
    6 HD14690--F0Vn   7083 +/- 150    0.48   14   20.33 +/- 0.358   0.49 +/- 0.12   ...XXX.
    7 HD14691--F0V    7062 +/-  94    0.22   15   19.52 +/- 0.228   0.49 +/- 0.08   ....XX.
    8 HD15130--A0V    13879 +/- 356   0.12   29   75.23 +/- 3.14   0.25 +/- 0.04   .....XXXXXXX.
    9 HD16673--F6V    6244 +/-  62    0.20   30   13.99 +/- 0.159   0.53 +/- 0.08   .........XX.
   10 HD16970--A3V    10309 +/- 130   0.13   36   160.2 +/- 2.37   0.65 +/- 0.08   ....XXXXXXXX
   11 HD17616--K2V    4339 +/-  59    0.72    7   7.817 +/- 0.335   0.81 +/- 0.23   ..X....X.
   12 HD17791--K5V    2845 +/- 143    4.14    2   13.03 +/- 1.59   2.44 +/- 1.44  XX..
   13 HD18012--G8V    4496 +/-  45    0.32    7   8.001 +/- 0.23   0.77 +/- 0.15   ..X....X.


### Simbad query results ###
# Simbad Search HD 11803: Type: Variable Star   F7V+..., V=6.01
Type: Variable Star
ICRS 2000.0 = 01 55 53.8319 +01 50 59.935 A [19.06 8.29   56] 1997A&A...323L..49
P
FK5 1950.0 = 01 53 18.61 +01 36 10.9 A [106.23 48.22   55] 1997A&A...323L..49P
FK4 1950 = 01 53 18.59 +01 36 10.8 A [106.20 48.22   56] 1997A&A...323L..49P
 gal = 153.67 -57.12
 mb, mv =  6.57  V?    6.01    ---   sp type = F7V+...
 pm = 158.44 190.44 A [  2.09   .95   56] 1997A&A...323L..49P
 rv = v +30.4 B [ 2] 1953GCRV...C.....0W
```

Save   Close

Photometric fits...

Gnuplot

F_lambda (erg cm^{-2} s^{-1} um^{-1})   HD14386--M7IIIe

BB Model Fit
Flux data
Retained data

Teff = 4240 +/- 1813 K

Fbol = 2.018 +/- 2.88 * 10^-8 erg cm^{-2} s^{-1}

Diam = 0.43 +/- 2.25 mas

Frac Error

Fit Residuals

Wavelength (um)

Sky coverage - annually and nightly

Annual calendar
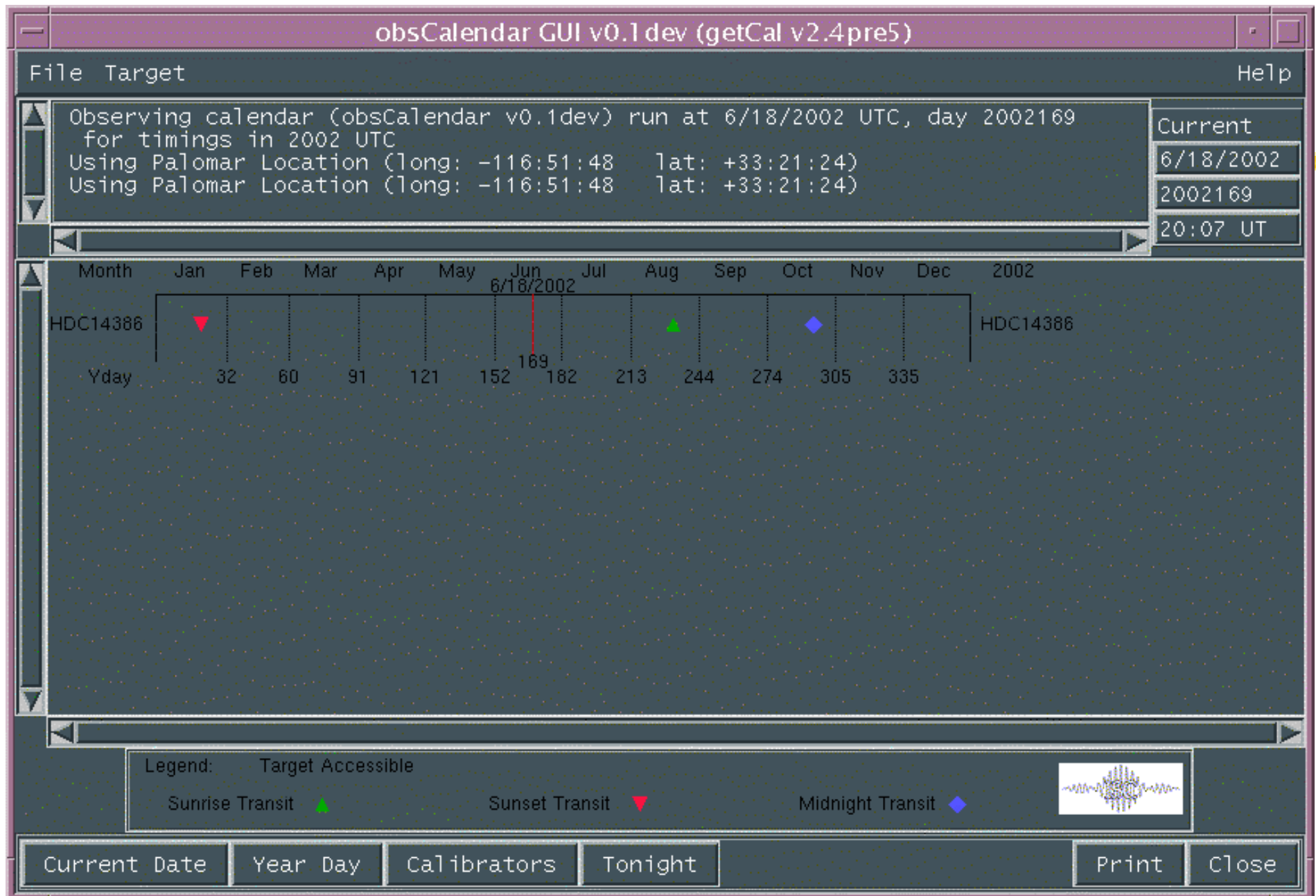
Nightly scheduling
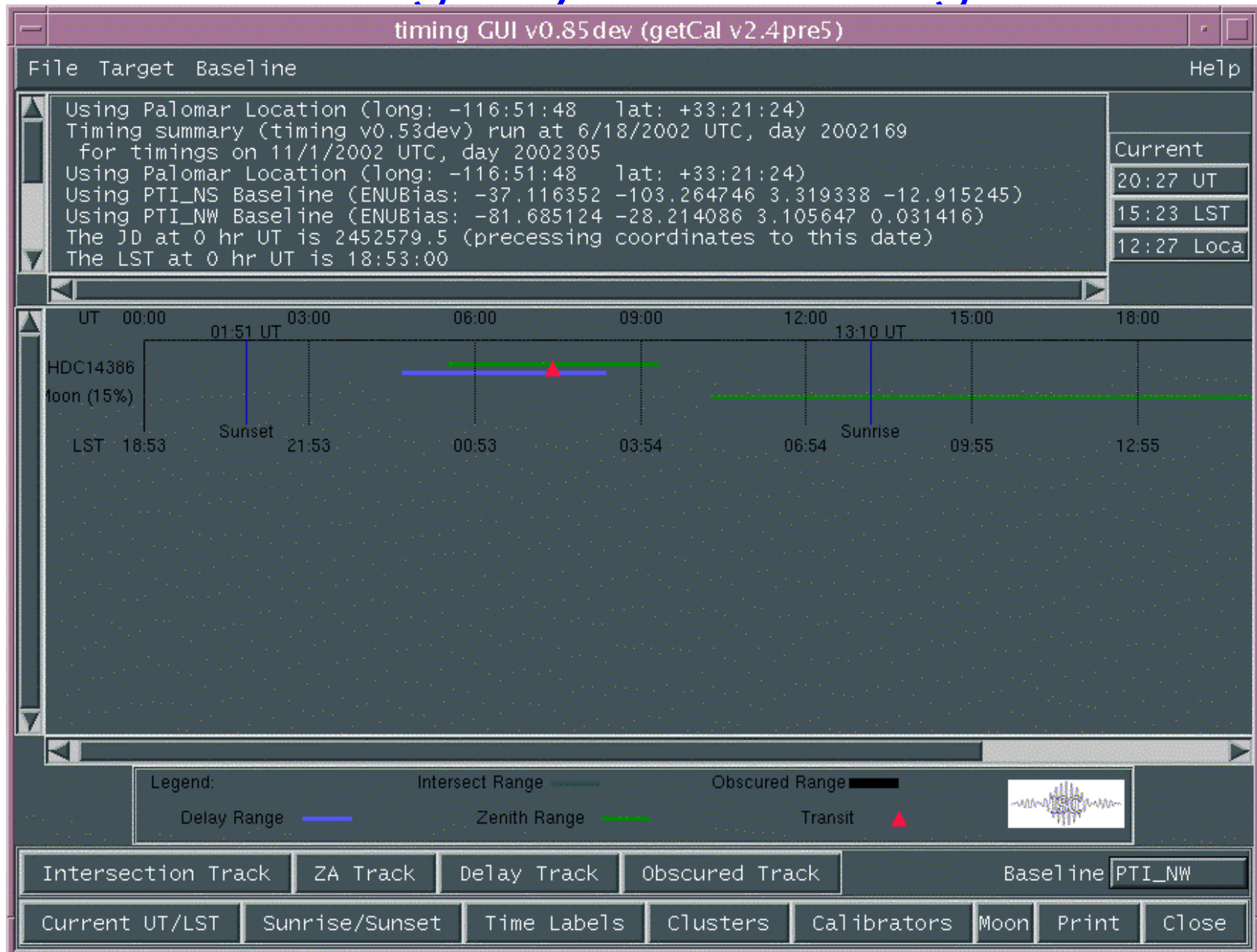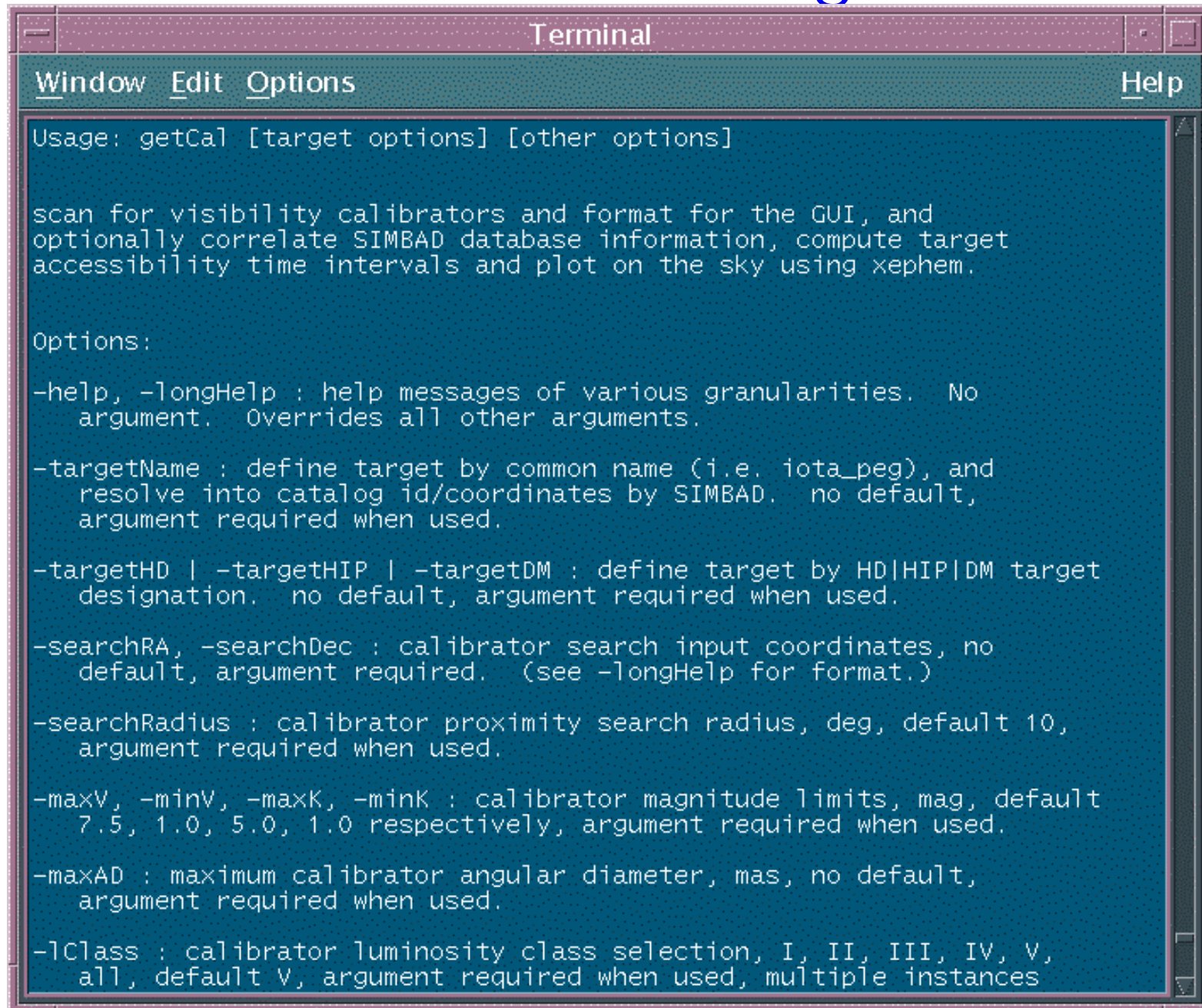
UV Information
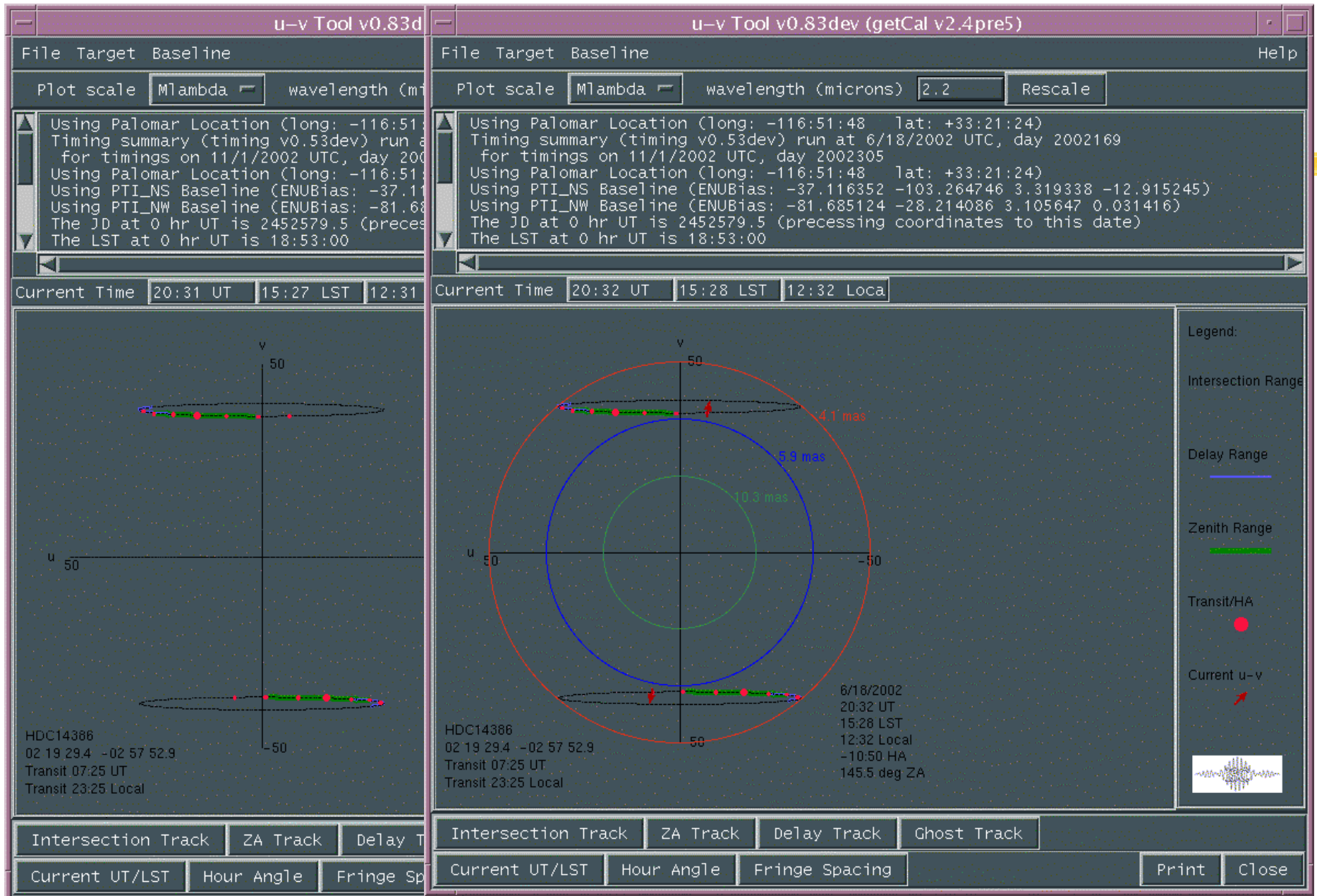
Command line interface: getCal -help


```
Terminal

Window  Edit  Options                                    Help

Usage: getCal [target options] [other options]


scan for visibility calibrators and format for the GUI, and
optionally correlate SIMBAD database information, compute target
accessibility time intervals and plot on the sky using xephem.


Options:

-help, -longHelp : help messages of various granularities.  No
    argument.  Overrides all other arguments.

-targetName : define target by common name (i.e. iota_peg), and
    resolve into catalog id/coordinates by SIMBAD.  no default,
    argument required when used.

-targetHD | -targetHIP | -targetDM : define target by HD|HIP|DM target
    designation.  no default, argument required when used.

-searchRA, -searchDec : calibrator search input coordinates, no
    default, argument required.  (see -longHelp for format.)

-searchRadius : calibrator proximity search radius, deg, default 10,
    argument required when used.

-maxV, -minV, -maxK, -minK : calibrator magnitude limits, mag, default
    7.5, 1.0, 5.0, 1.0 respectively, argument required when used.

-maxAD : maximum calibrator angular diameter, mas, no default,
    argument required when used.

-lClass : calibrator luminosity class selection, I, II, III, IV, V,
    all, default V, argument required when used, multiple instances
```
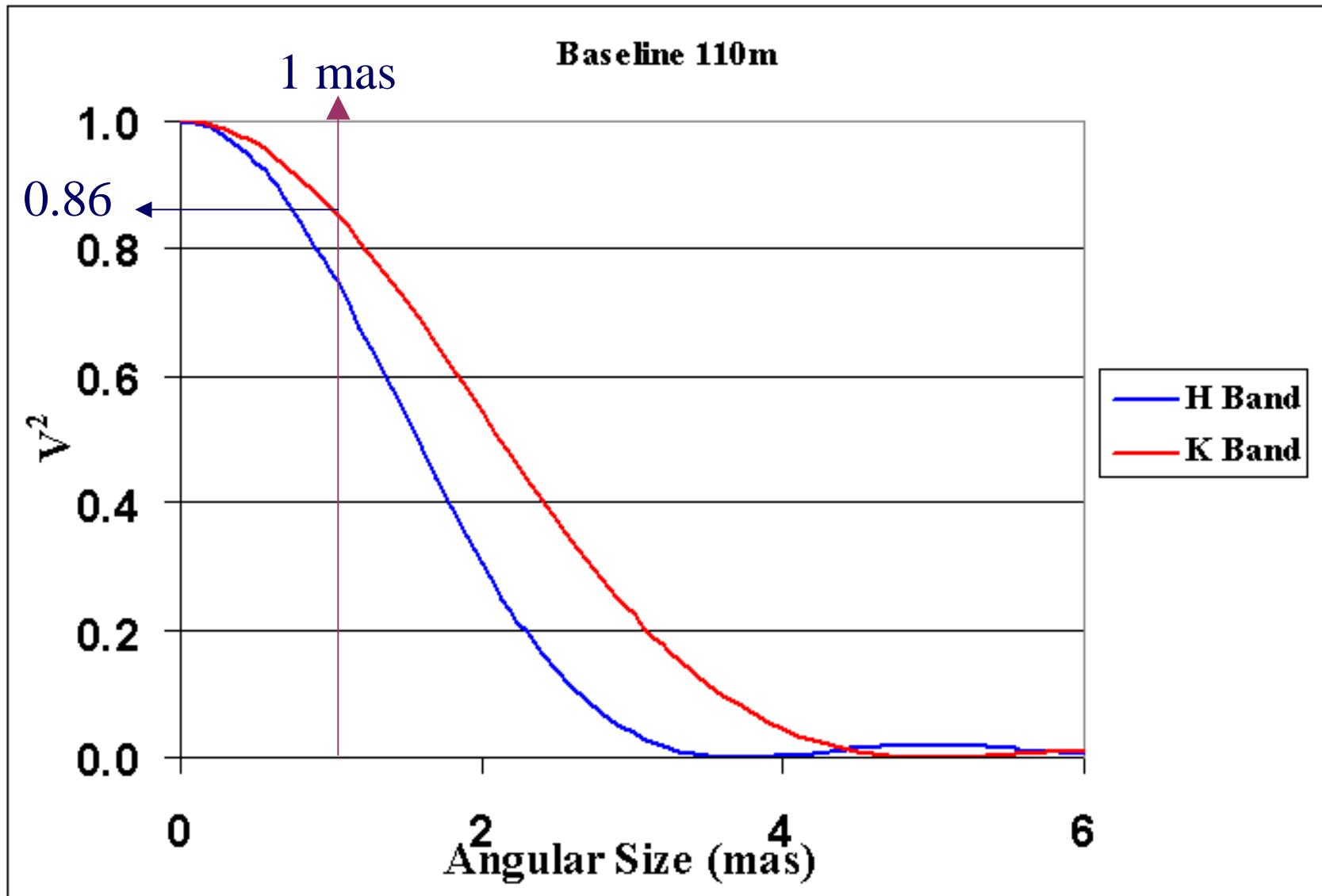
Target Vetting Criteria

⌘Basic Information
- ⌃Resolved/Unresolved
- ⌃Singular or apparently so (Hipparcos/Simbad)
- ⌃Sky coverage - compatibility with target(s)
  - ☒UV Tracks
 - ☒Annual availability
- ⌃Magnitude (SNR)

(Un)resolved sources

Hipparcos Flags

- Variability (V) - classed as a number depending upon mag. of variations
- Orbital solution (O) - orbital soln. found with SMA separation and period
- Components solution (C) - individual components in multiple system resolved and separated with PA
- Stochastic Motion (X)
- Acceleration or higher order terms (G)

Sky Coverage Limitations

Delay and Zenith Angle Limits, PTI
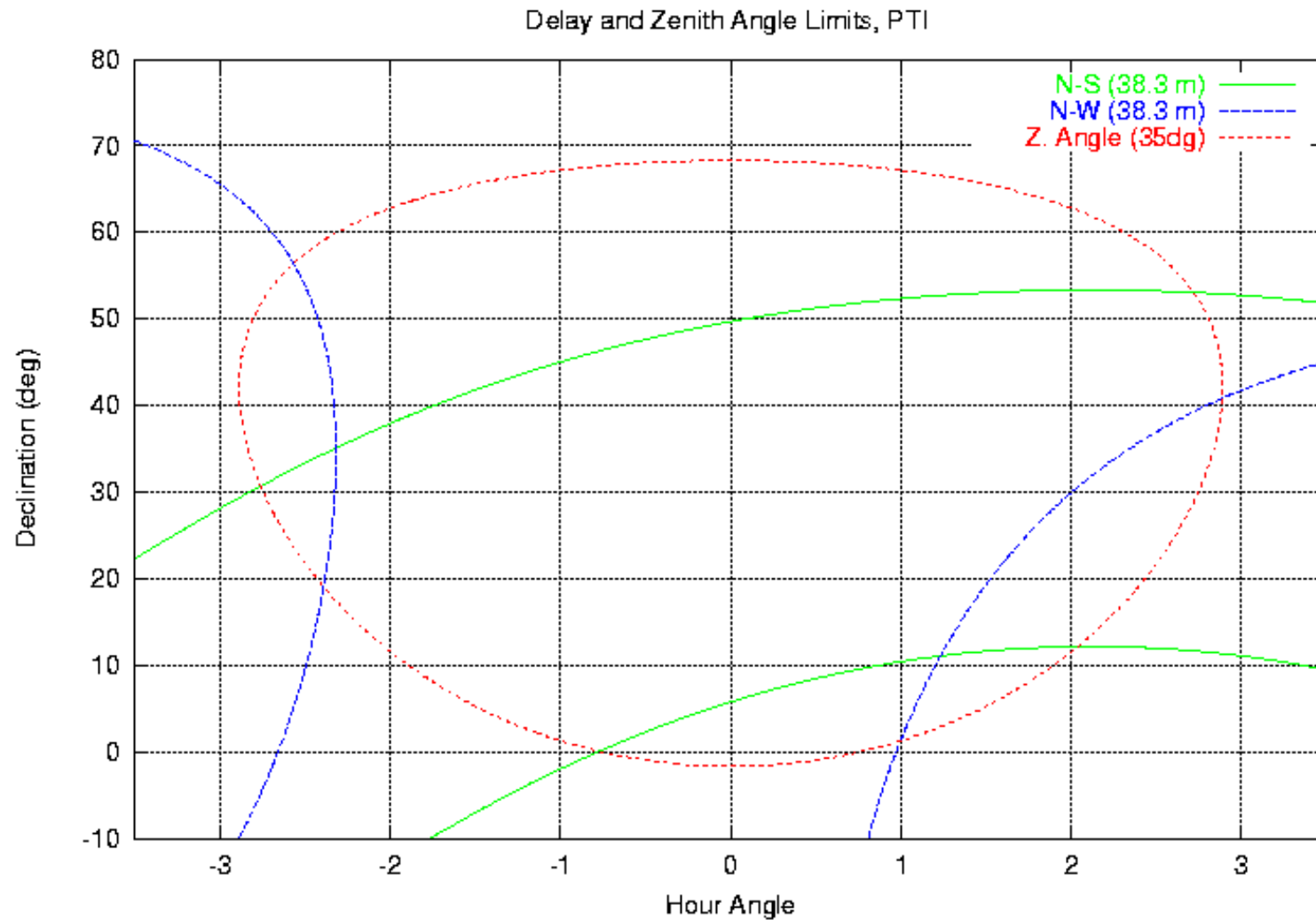
Magnitude Limits at PTI

⌘ K Band - Reliably acquire data down to about 5th mag. with current dewar

⌂ New dewar - have acquired well below 6.5 mag., expect to work reliably close to that range

⌘ H and J bands - About 1-1.5 mag. brighter, depending upon sky conditions

- Diameter
  - Spectral Type
  - Estimated bolometric flux
- SIMBAD/ADS - Red Flags
  - Sanity check (SpTy, distance, magnitudes)
  - Variability
  - Double/confused
  - Fast rotator
  - Calibration standard
  - Papers - how many, what types, anything odd
- Real data - acid test
  - (un)resolved nature
  - nightly and long-term variations
  - SNR, color, other "gotchas"

Experiment 1

⌘ Altair

⌂ HD187642, A7IV-V, 194.95 mas parallax

⌂ Photometric fits: T=8156+/-83K, 3.22+/-0.46 mas diameter

⌂ Rapid rotator - we are looking for asymmetry with respect to hour angle
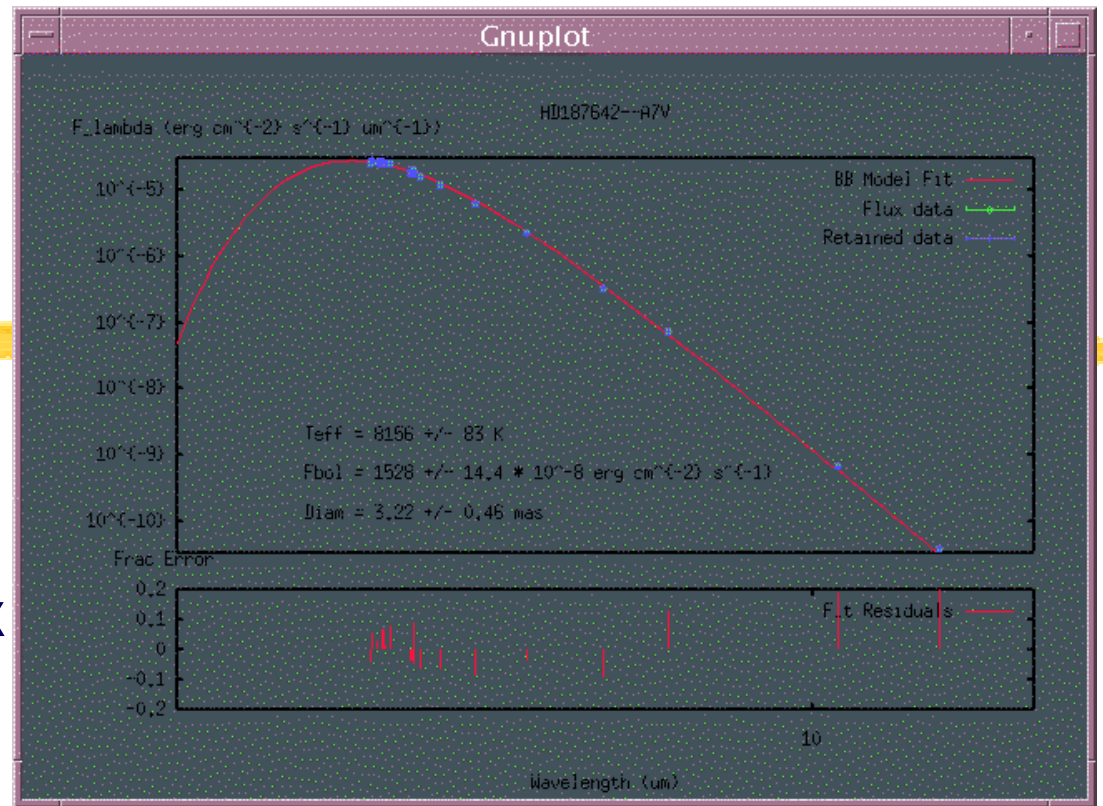
Experiment 2

⌘ Mira

⌃ HD14386, M7IIIe, 7.79 mas parallax

⌃ Photometric fits from Fbol are bad...expect temp. around 3000 K

⌃ Prototype mira variable star (R~250R$_{sun}$)- looking for evidence of pulsation with phase
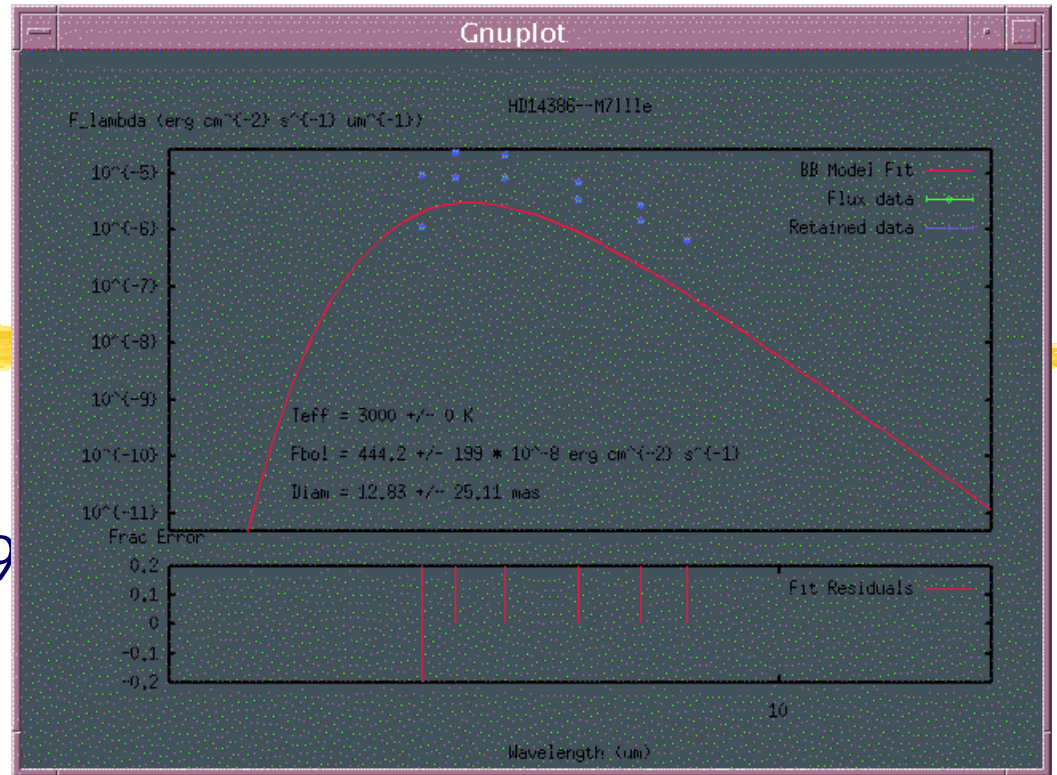
Experiment 3

⌘TZ Tri

⌃HD13480, G5III+, 10.68 mas parallax

⌃Photometric fits suggests 1.33 +/- 0.33 mas on primary

⌃Hipparcos separates 2 components @ 3.9″

⌃RS CVn type variable spectroscopic binary for which we want to obtain an orbital solution
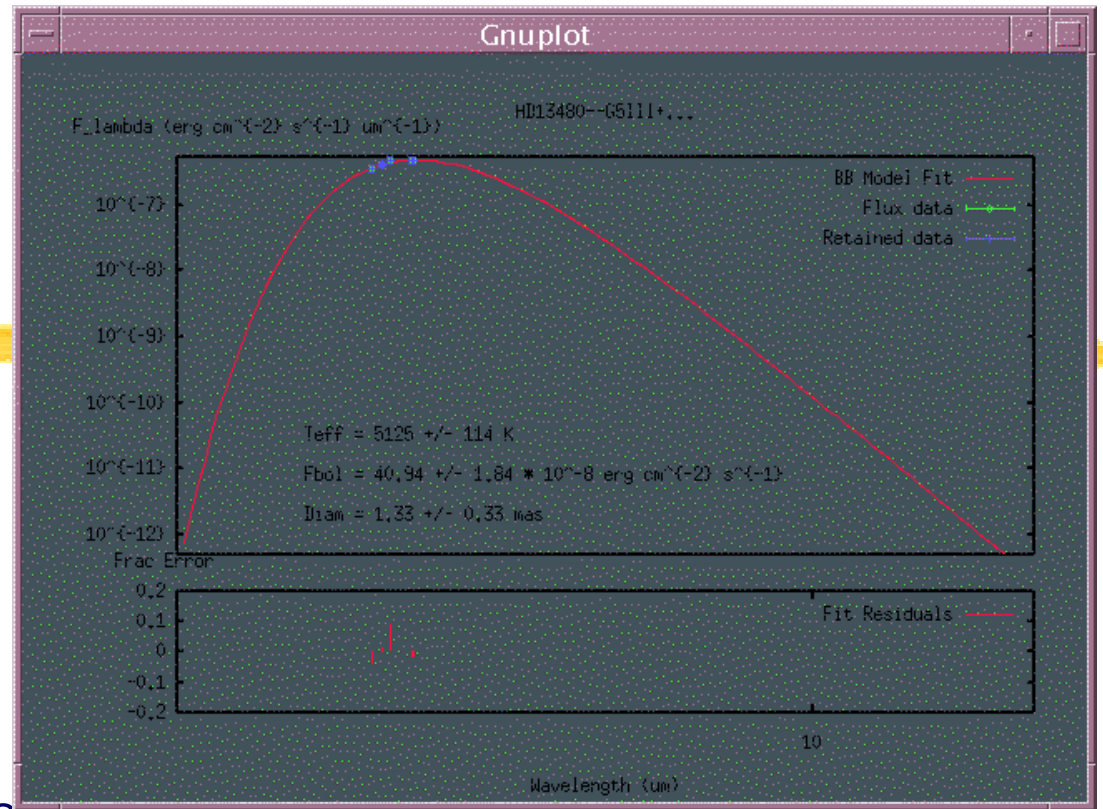
Lab Time...................

Altair Options:

⌘ <10° sep., <1.0 mas, > 4.5@K, no flags

- HD182900, HD183227, HD187691, HD188350, HD189090, HD189322, HD190406

⌘ <10° sep., >1.0 mas, > 4.5@K, no flags

- HD181122*, HD183492, HD184013, HD187660, HD189322*, HD193373, HD194013, HD194937

- * = ancillary photometric info suggests resolved

Altair choices in practice:

⌘ HD187691 - F8V @ 1.6° sep. and about 0.72 mas in diameter

⌘ HD187923 - G0V @ 2.8° sep. and about 0.55 mas in diameter - not on original list as it was too faint

⌘ Comparison to Vega rather than nearby resolved calibrator

⌘ van Belle et al., 2001, ApJ, 559, 1155.
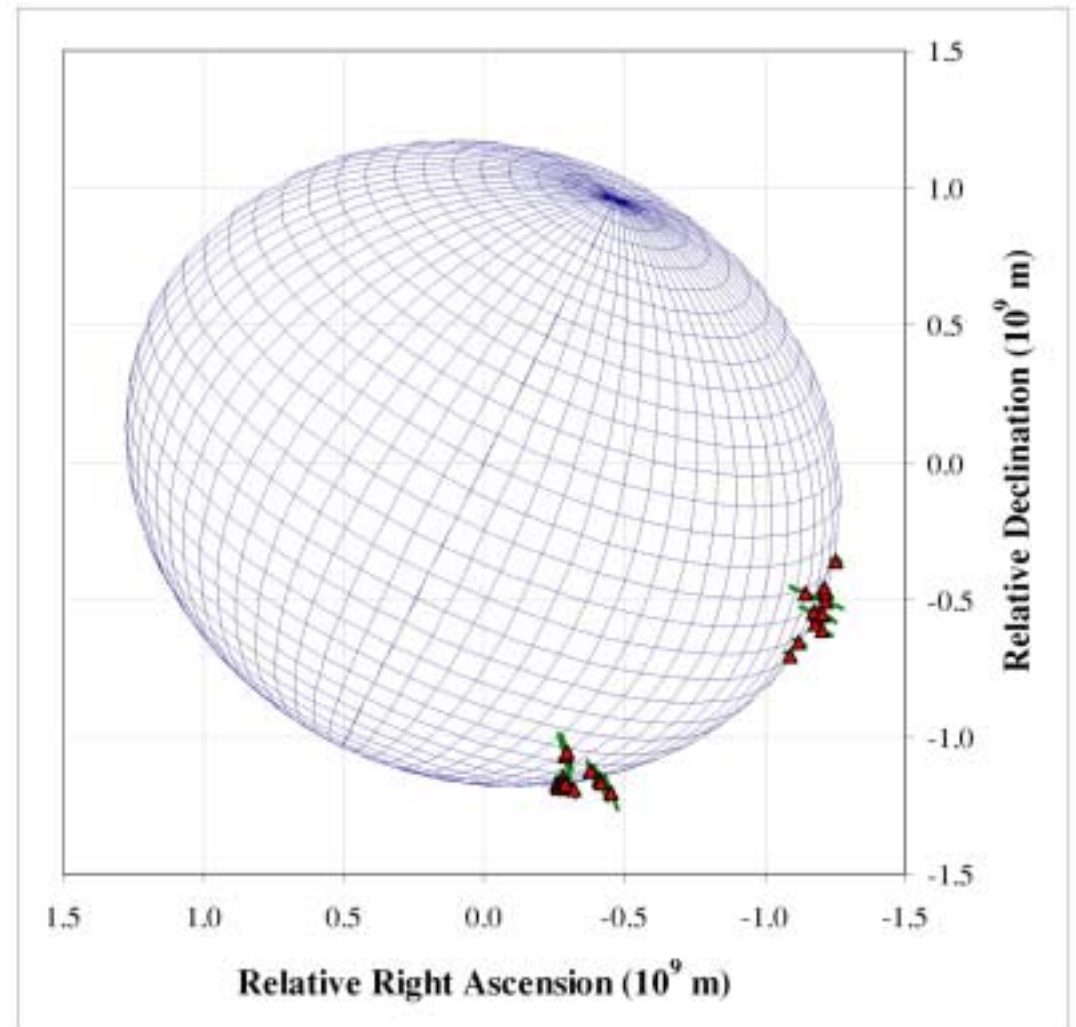
Mira Options:

⌘ <10° sep., <1.0 mas, > 4.6@K, no flags, dec no too low

⌃ HD12573, HD15004, HD15328, HD15633, HD16824, HD17616

⌘ <10° sep., <1.0 mas, > 4.5@K, no flags, dec no too low

⌃ HD12641*^, HD13468, HD14129, HD15694, HD15779, HD16400, HD17791*

⌃ * = ancillary info. suggests larger diameter

⌃ ^ = different SpTy from ancillary info - RED FLAG

Mira note:

- If you used basic info given to date you might have noticed Mira is too large for PTI
  - $\Theta = d / D$ where $d = 500 R_{sun}$ & $D = 128$ pc
  - $d = 3.5E11m$ & $4.0E18m$ & 1 rad$=206265''$
  - $\Theta = 18$ mas

- If you had checked the literature you would have noticed that Ridgway (1992, AJ, 104) observed it to have a size of 36.1+/-1.1 mas at 2.2 microns

TZ Tri Options:

⌘ <10° sep., <1.0 mas, > 5.0@K, no flags

⌃ HD9714, HD10095, HD11007, HD12402*, HD12535, HD12638, HD13555, HD13691, HD14067, HD14055, HD14875^, HD15257^*, HD15335, HD15673, HD16176, HD16220, HD17228, HD18202^

⌘ <10° sep., 1.0-2.0 mas, > 5.0@K, no flags

⌃ HD10348*, HD10975, HD11453^, HD13363, HD13747, HD14969^, HD15152, HD15176, HD15464, HD17361*

⌃ * = ancillary info suggests different diameter range

⌃ ^ = no available photometry to estimate size

TZ Tri choices in practice:

- ⌘ On our list: HD14055 & HD15335

- ⌘ Not on our list: HD18411 (13.3° sep), HD17573 (var), and HD11973 (double)

- ⌘ Data taken before the existence of getCal suite all calibrators used were unresolved to PTI

- ⌘ Results: Assuming R~0.3 @ 2.2μm, a=1.2+/-0.1mas and $M_{tot} <= 1.5 M_{Sun}$

- ⌘ Koresko et al. 1998, ApJ, 509, L45.
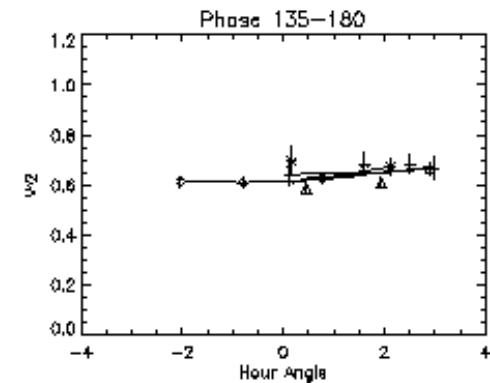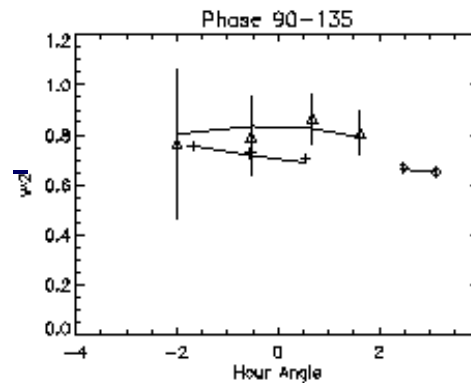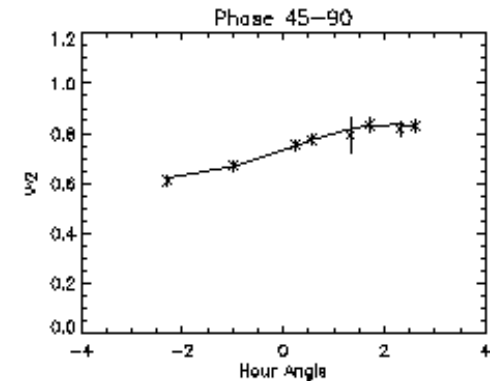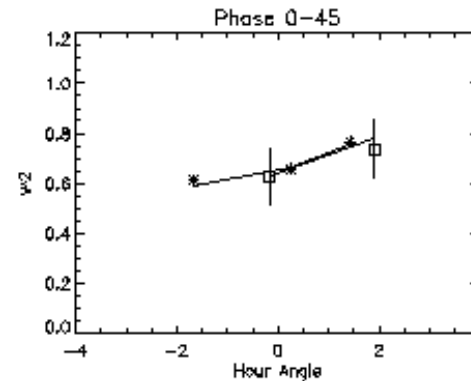
PTI Collaboration:

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⌘G. Vasisht

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  ⌂K. M. Rykoski

http://huey.jpl.nasa.gov/palomar/index.html

Software:

⌘ This work has made the use of software produced by the Interferometry Science Center at the California Institute of Technology